Development of Materials/Processes for Fusion Applications at Thor Technologies, Inc.

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Briefing Outline

- Company Background
- Technology Backgrounds
- Recent & On-Going Efforts
- Teaming

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Company Background

- Business Focus
  - Manufacture of Ceramics & Ceramic Composites Using Preceramic Polymers
    - *Fiber Reinforced Ceramic Composites*
      - NDE Technology
    - *Hybrid Metal/Ceramic Composites*
    - *Ceramic Coatings*
    - *Nanosize/Nanostructured Ceramics*
- Woman-Owned, Very Small Business
  - Incorporated November 1999
  - NSF STTR Grant January 2000
  - Currently 4 Employees
    - *2 Ph. D. & 2 B.S.*
- Network of Collaborators & Subcontractors
  - LANL, SNL, SwRI, at al

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Technology Background

- Resolution of Ceramic Processing Issues
  - Powder Consolidation Inherently Limited
    - *Brittle Fracture*
    - *Machining Slow & Costly*
  - CVD Processing Slow & Costly
    - *Weeks & Months*
    - *High Capital Cost*
  - Bonding & Joining Problematic
  - Coatings - Time & Equipment Intensive

Solutions Sought Through Innovative Application of Chemical Synthesis Combined with Novel Processing Methods

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Preceramic Processing

- Polymeric Precursors to Ceramics
  - Enables Utilization of Well-Developed Polymer Composite Processing Technologies
    - *Near Net-Shape*
    - *Process Monitoring*
- High Frequency Microwave Heating (Gyrotron)
  - Very Rapid, Uniform Heating
  - Enables Co-Processing with Metal Inserts
    - *Facilitates Bonding/Joining*
    - *Enables New Material Designs*

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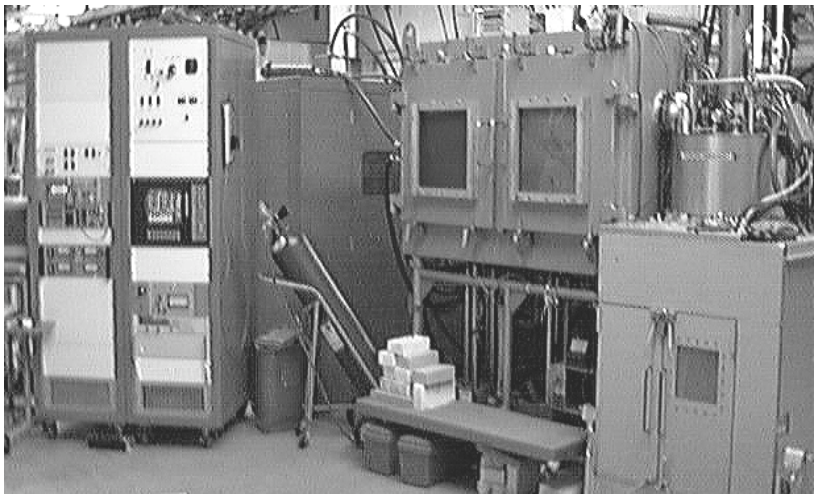
High Frequency Microwave Heating

- High Frequency Microwave (≥25GHz)
  - Huge Reduction in Firing Time
    - *⇒ 1300˚C in minutes, NOT hours*
  - Uniform Heating Through Thickness
    - *In Irradiated Area (Beam)*
  - **Metals Unaffected**



High Frequency Microwave (Gyrotron) Facility at LANL

Co-Processing Yields Potential to Apply Simple, Traditional Bonding/Joining Technologies to Ceramic Composites

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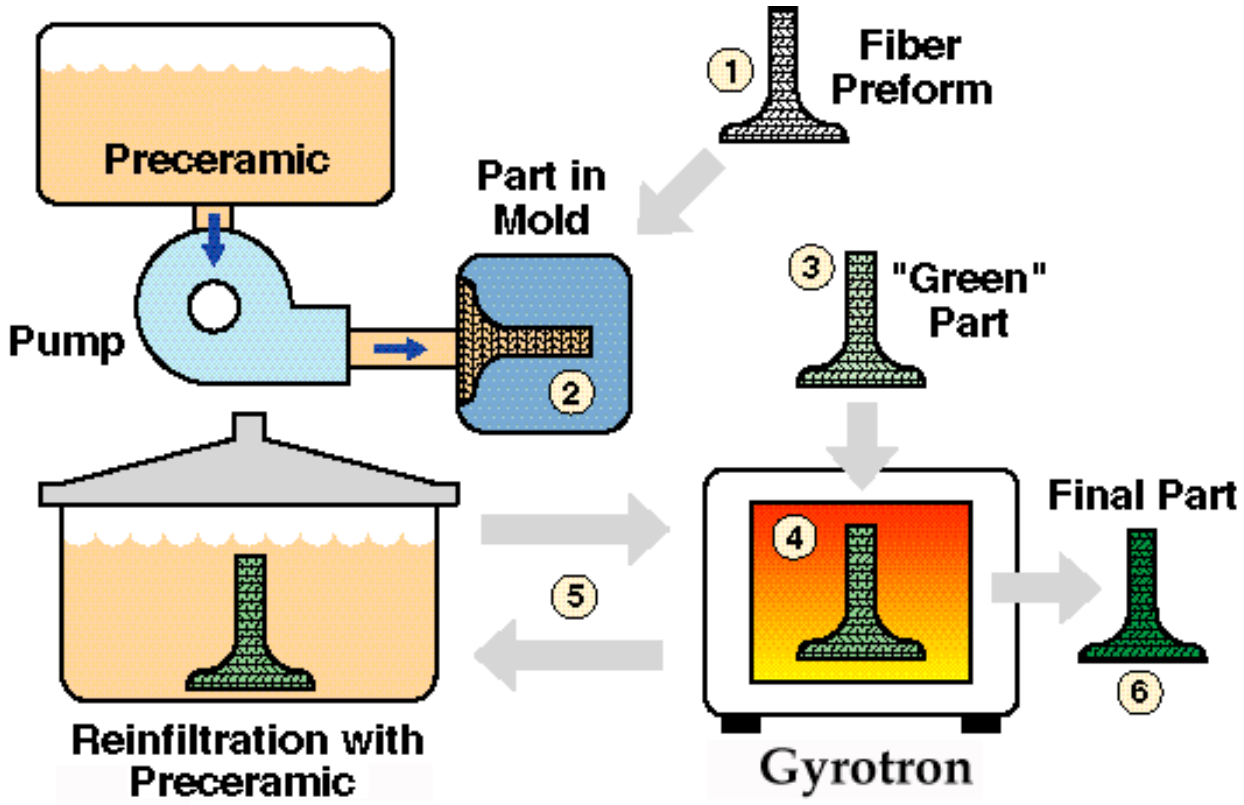
Ceramic Composite Processing

- Polymer Infiltration/Microwave Pyrolysis (**PIMP**) Processing of Fiber-Reinforced Ceramic Composites (FRCs)



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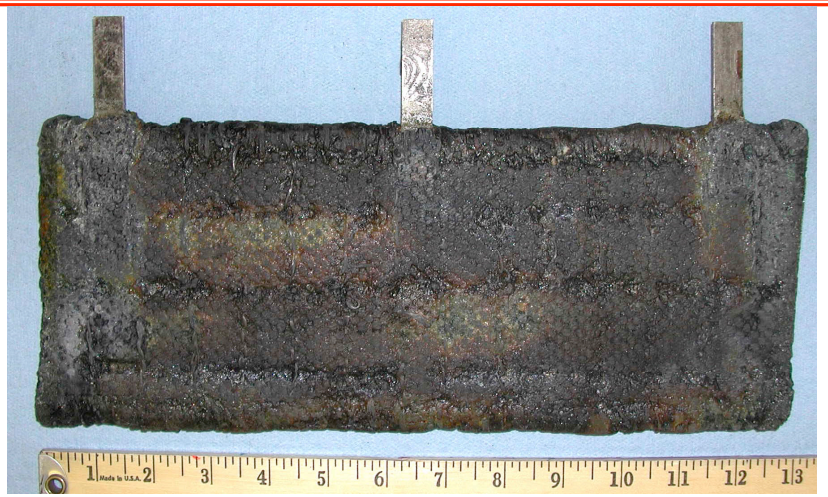
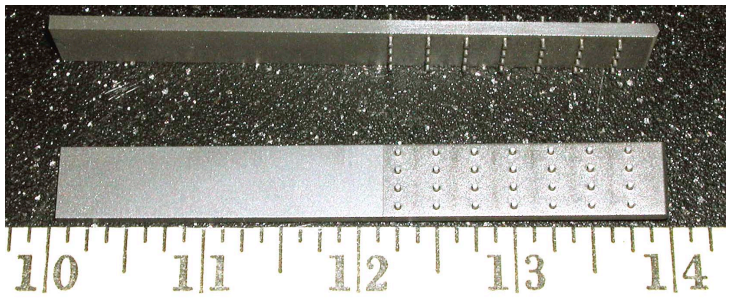
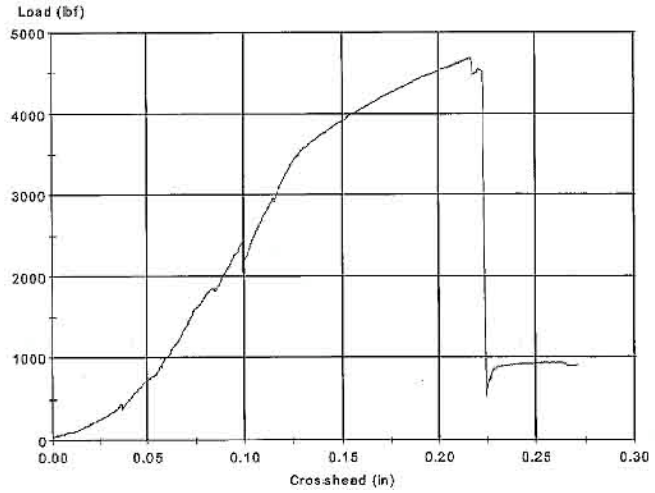
Hybrid Metal/FRC Composite

- Inconel 625 Inserts
  - "Pins" Sheared Easily
- Panex 30 Fabric
  - Non-Aerospace Grade
- Polymer-Derived SiC Matrix
- Processed Without Autoclave
- "Pull-Tests" at CTL
  - ***Metal Failed Before FRC***



Carbon Fiber-Reinforced Silicon Carbide with Inconel 625 Inserts





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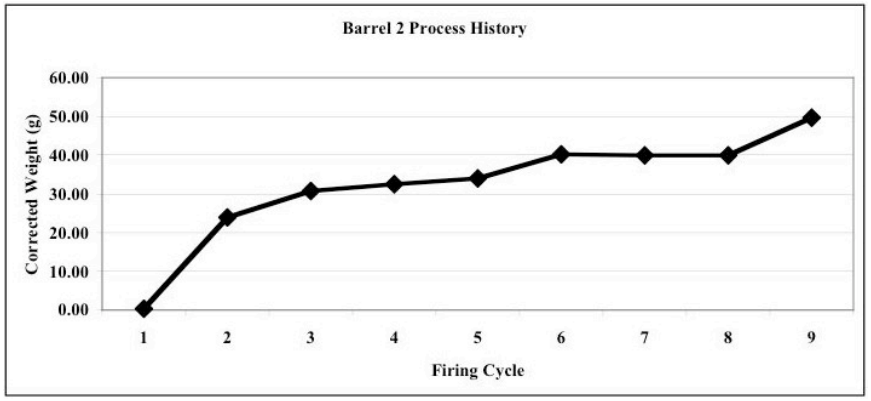
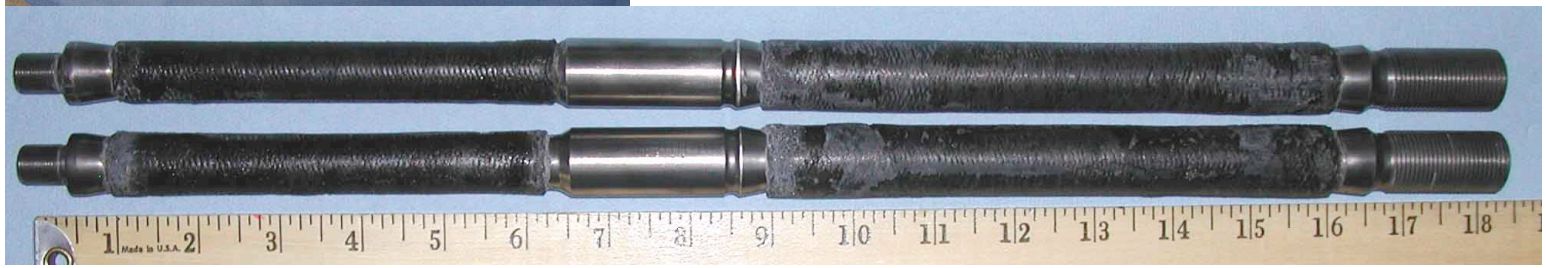
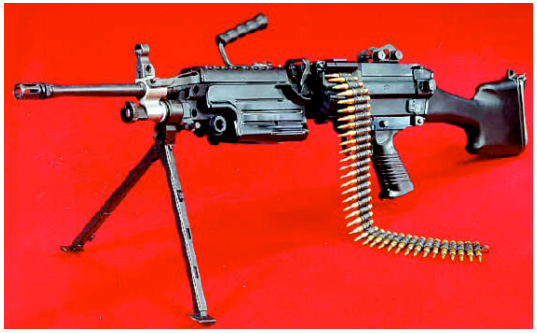
USMC M249 SAW Barrel Tube





- Excess Metal Removed from Standard M249 Barrel
- Braided T-300 Carbon Fiber Applied
  - Amorphous Carbon Interface
- SiC Matrix Densification
  - PIMP Process



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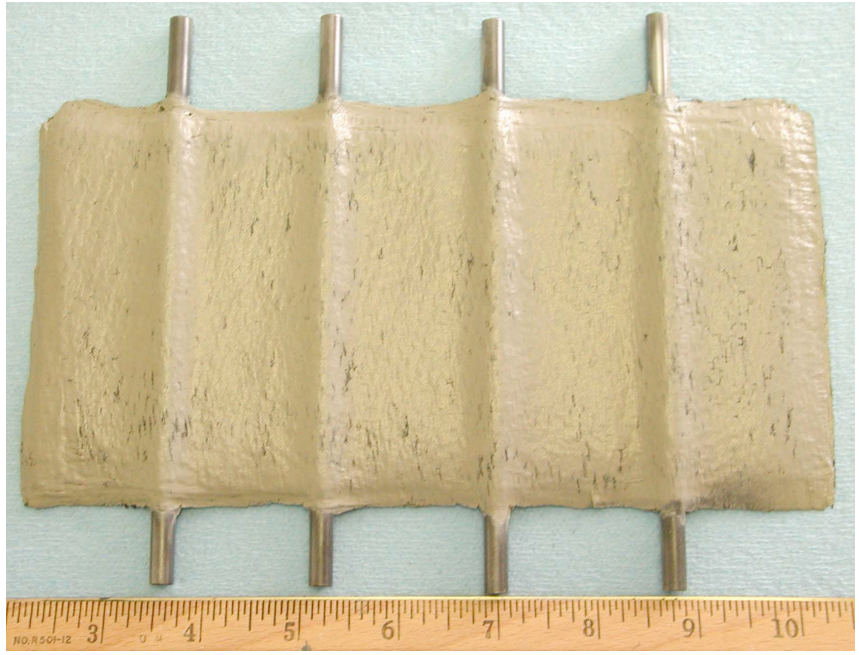
Current NASA Phase I

- Extend Hybrid Metal FRCs to Actively Cooled Structures
  - Fewer Process Steps
  - Assembly & Verification of Coolant Manifold Prior to Component Mfg

SiC-Fiber Reinforced
"SiC" Panel With
Molybdenum Tube Inserts
(processing currently underway)



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Fusion Applications

- Rapid, Low Cost Approach to SiC/SiC
- Enables Simple Mfg of Cooled Components
- Simplifies Assembly/Repair
  - Low Activation Metal Attachment Lugs
  - "Nuts & Bolts" Attachment Strategy
  - Preceramic "Caulk" Gap Sealant

Applicability to Thick Sections?
ALL FRC Processing Methods Problematic

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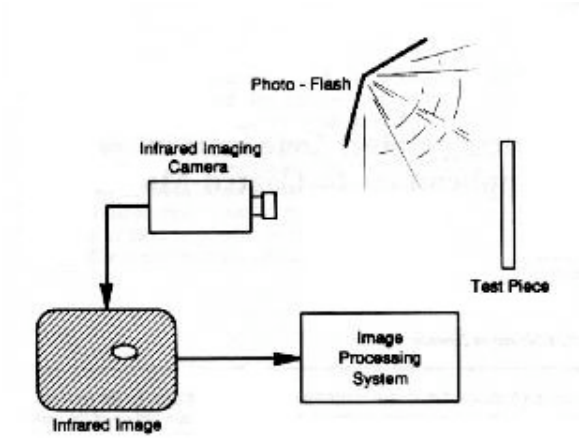
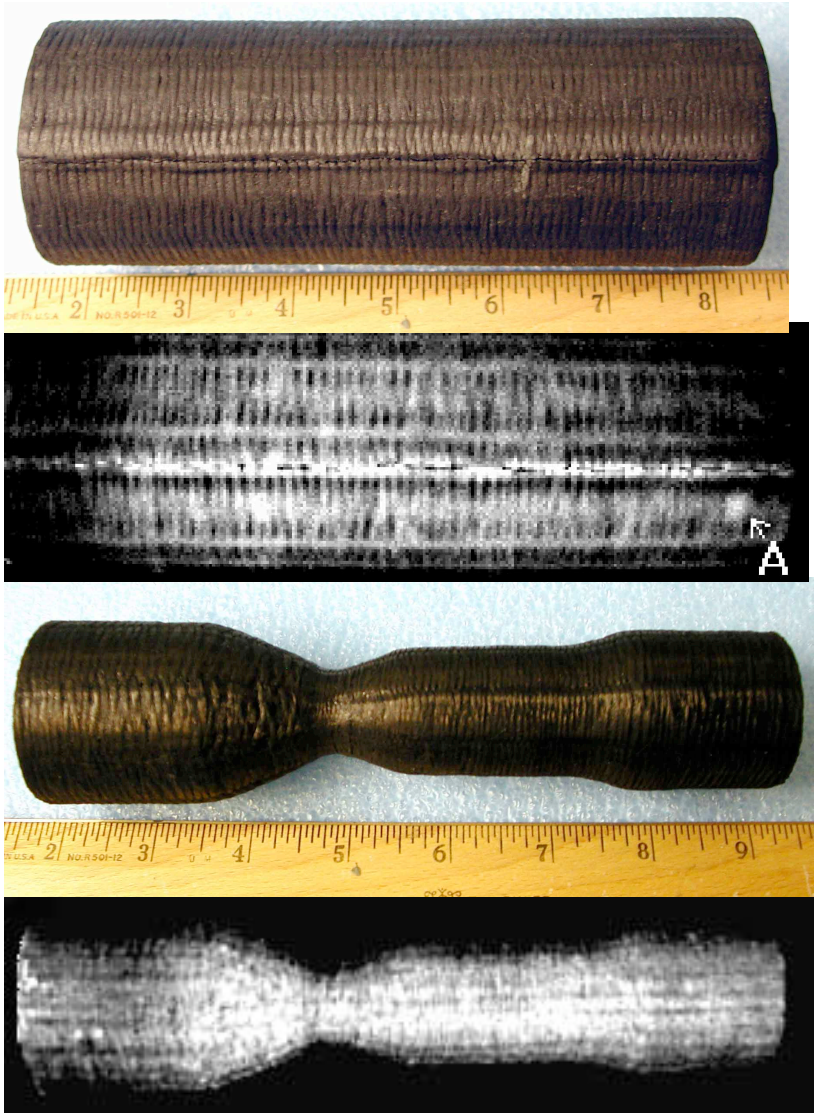
Development of NDE for FRCs

- Phase I SBIR MDA/SMDC DACS Nozzle
- Low Cost C/SiC Process
  - 2” ID Braided Tubes
  - “Prototype” Nozzle
- Simple NDE Method Demonstrated
  - Flash Thermography





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Sol-Gel Coating Technology

- Simple Method for Producing Ceramic Coatings
  - Excellent Control of Chemistry
  - Simple Application Methods (paint, spray)
- Original Developments at Thor Directed at TBCs
  - Simple, “On-Site” Repair of Damaged TBCs on Turbine Hot-Section Components.
  - DoE STTR Phase I, “Demo” Funding from EPRI (current)
- Direct Application to MHD Mitigation
  - Direct Deposition of Coating
  - Precursors for Plasma (PIIP) Processes
  - Yttrium Oxide, Erbium Oxide, Aluminum Nitride (?)
  - Phase I Proposal Submitted to DoE

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On-Going, Supporting Efforts

- **Phase I SBIRs**
  - NASA-MSFC
    - *Actively-Cooled FRC Panel*
      - SiC/SiC with TZM Molybdenum Inserts
    - *January 2004 Start*
  - MDA
    - *C/SiC Mirror Processing*
      - Award Letter Received
        - » Contract Pending
    - *Refractory Matrix Ceramics for CAV TPS*
      - Award Letter Received
        - » Contract Pending
  - Navy
    - *Solid Oxide Lubricant via Sol-Gel PIIP*
      - Award Letter Received
        - » Contract Pending
- **Commercial:**
  - Boeing
    - *On-Orbit Repair for C/C*
  - EPRI
    - *On-Site Repair of TBCs*

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